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(54) **REAL-TIME RULE ENGINE FOR ADAPTIVE TESTING OF INTEGRATED CIRCUITS**

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(52) **U.S. Cl.**

CPC ***G06F 11/263*** (2013.01); ***G01R 31/31905*** (2013.01); *G01R 31/31903* (2013.01); *G01R 31/31908* (2013.01)

(58) **Field of Classification Search**

USPC 714/33

See application file for complete search history.

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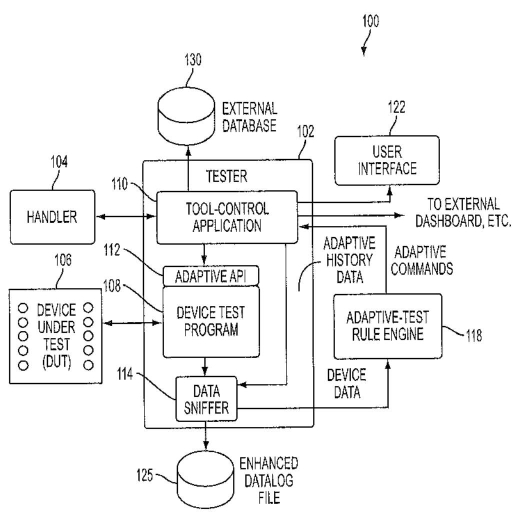
(57) **ABSTRACT**

A method of testing a device is disclosed. Test data is obtained for a device testing program that tests the device. An adaptation command for testing the device is determined at an adaptive testing engine using obtained test data. The adaptation command is sent from the adaptive testing engine to a tool control application. The tool control application uses the adaptation command to control an operation related to the testing of the device.

12 Claims, 2 Drawing Sheets



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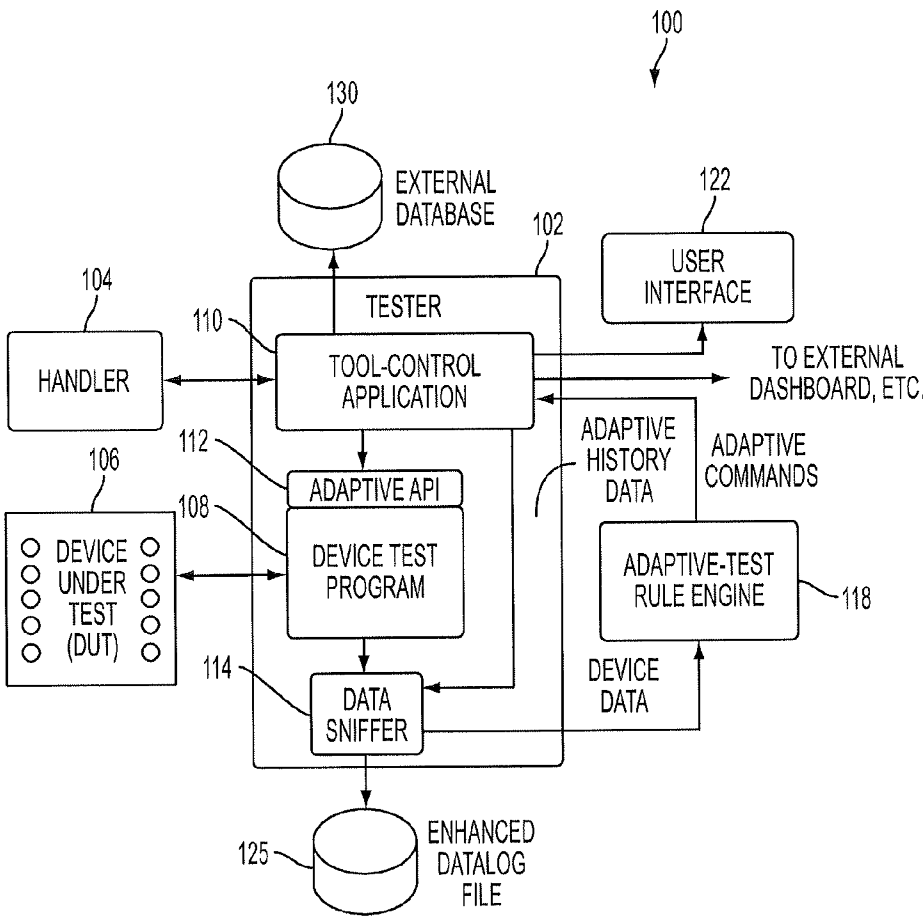
100
130
EXTERNAL DATABASE
102
122
USER INTERFACE
104
TESTER
110
HANDLER
TOOL-CONTROL APPLICATION
TO EXTERNAL DASHBOARD, ETC.
112
ADAPTIVE HISTORY DATA
ADAPTIVE COMMANDS
106
ADAPTIVE API
108
DEVICE UNDER TEST (DUT)
DEVICE TEST PROGRAM
ADAPTIVE-TEST RULE ENGINE
118
114
DEVICE DATA
DATA SNIFFER
125
ENHANCED DATALOG FILE

FIG. 1

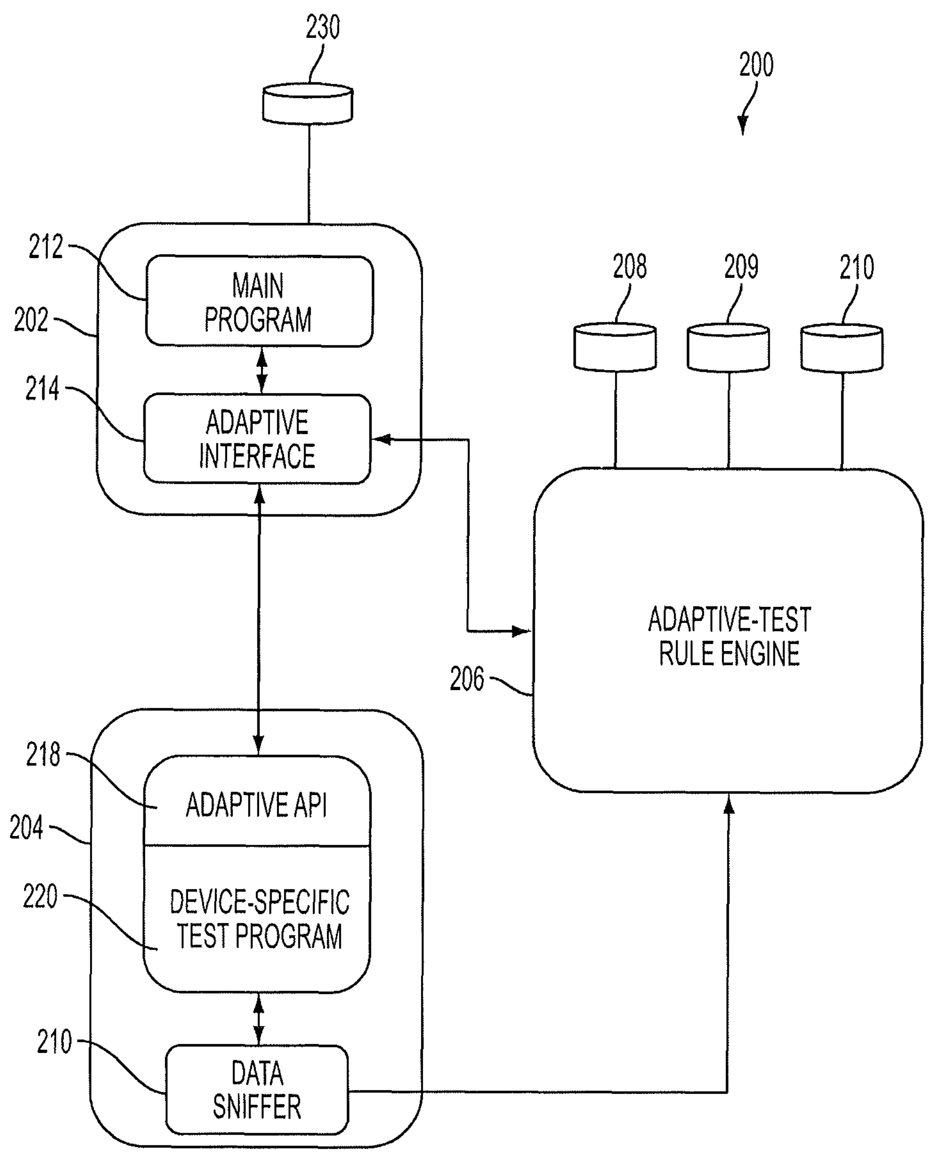
230
200
212
MAIN PROGRAM
202
214
ADAPTIVE INTERFACE
208
209
210
ADAPTIVE-TEST RULE ENGINE
206
218
ADAPTIVE API
204
220
DEVICE-SPECIFIC TEST PROGRAM
210
DATA SNIFFER

FIG. 2

REAL-TIME RULE ENGINE FOR ADAPTIVE TESTING OF INTEGRATED CIRCUITS

This application is a continuation of U.S. patent application Ser. No. 13/591,855, titled "REAL-TIME RULE ENGINE FOR ADAPTIVE TESTING OF INTEGRATED CIRCUITS," filed Aug. 22, 2012, the disclosure of which is incorporated by reference herein in its entirety.

BACKGROUND

The present disclosure relates to testing integrated circuits and, in particular, to a method of controlling a behavior of a test cell that tests integrated circuits.

The complexity of integrated circuits is constantly increasing. In order to ensure quality of these increasingly-complex circuits, integrated circuit testers have been designed to run a battery of tests on the integrated circuits during various manufacturing stages as well as on the integrated circuit as a final product. Typical integrated circuit testers run a device test program that is coupled to the integrated circuit, tests the integrated circuit and collects data from the integrated circuit in response to the test. These integrated circuit testers may further be coupled to an adaptive test engine separate from the device test program that analyzes the test data and determines an adaptive action that alters the device test program in order to optimize some aspect of the testing process. These adaptive test engines are limited to implementing adaptive actions directly related to testing the integrated circuit device.

SUMMARY

According to one embodiment, a method of testing a device includes determining an adaptation command for testing the device at an adaptive testing engine using data obtained from a device testing program that tests the device; sending the adaptation command from the adaptive testing engine to a tool control application; and using the adaptation command at tool control application to control an operation related to the testing of the device.

According to another embodiment, a method of controlling a test cell that tests a device includes: operating a device test program using a tool control application; receiving an adaptation command at the tool control application; and altering a parameter of the test cell based on the adaptation command to control the test cell.

Additional features and advantages are realized through the techniques of the present disclosure. Other embodiments and aspects of the disclosure are described in detail herein and are considered a part of the claimed disclosure. For a better understanding of the disclosure with the advantages and the features, refer to the description and to the drawings.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

The subject matter which is regarded as the disclosure is particularly pointed out and distinctly claimed in the claims at the conclusion of the specification. The foregoing and other features and advantages of the disclosure are apparent from the following detailed description taken in conjunction with the accompanying drawings in which:

FIG. **1** shows a schematic diagram of an exemplary test cell of the present disclosure; and

FIG. **2** shows an exemplary schematic drawing of an alternate embodiment of the test cell.

DETAILED DESCRIPTION

FIG. **1** shows a schematic diagram of an exemplary test cell **100** of the present disclosure. In various embodiments, the exemplary test cell **100** includes a tester **102** that runs various programs that perform tests on a device under test (DUT) **106** such as an integrated-circuit chip on a wafer, integrated circuit in a module package, etc. The DUT **106** is often one of a plurality of DUTs from a sample bin or sample group. The DUT **106** may have an associated part number and a group number identifying its inclusion in a given sample group. The DUT **106** may be in any stage of manufacturing, including a completed product. In an exemplary embodiment, the tester **102** selects the DUT **106** for testing by operating a handler **104**. The handler **104** may include various subsystems such as wafer selector, wafer probe, probe cleaner, etc., that are used to manipulate various physical aspects of the testing process. The handler **104** may select the DUT **106** from its sample group, place the probes at the selected DUT's location on the wafer and advance to a new DUT **106** once a test is completed. In another embodiment, the handler **104** may be designed to place an integrated circuit DUT **106** into a testing socket for testing and remove the integrated circuit from the testing socket once a test is completed. The handler is controlled by the tester **102**, and various parameters of the handler may be altered by the tester **102** using exemplary methods disclosed herein.

The tester **102** may include a number of programs that may be operated by one or more processors in order to perform various testing procedures disclosed herein. Exemplary programs that may be run on the one or more processors may include a device test program **108** for performing tests on the DUT **106**, a tool control application **110** for providing supervision of the device test program **108** as well as for performing additional tasks related to the testing process, an adaptive API (application program interface) **112** for provided commands from the tool control application **110** to the device test program **108**, and a data sniffer **114** for extracting data from the device test program **108** in real-time. In addition, a real-time adaptive-test rule engine **118** may be run on the one or more processors. In one aspect, the adaptive-test rule engine **118** receives test data from the data sniffer **114** and analyzes the data with respect to a set of rules and algorithms to determine a set of adaptation commands or directives that are then sent to the tool control application **110**.

The device test program **108** administers tests to the DUT **106**. In one embodiment, the device test program **108** is involved in various aspects of administering the tests including, but not limited to, sending signals to the DUT **106**, receiving signals from the DUT **106** in response to the sent signals, determining a condition or pass/fail status of the DUT **106** from the received signals, and storing data to a database or data file **125**. The adaptive API **112** is included in the device test program **108** and provides communication between the tool control application **110** and the device test program **108**. In one embodiment, the device test program **108** may receive instructions from the tool control application **112** through the adaptive API **112**. Exemplary instructions may include initiating the device test program **108** to run a test, altering a parameter of the test, and stopping or discontinuing administering of a part of a test. The exemplary instructions may be received and implemented during the testing process.

The tool control application **110** supervises the device test program **108** and controls various behaviors or activities of the test cell **100**. A behavior may be an activity that is not directly related to the function of administering tests at the device test program **108**. In one embodiment, the tool control application **110** may communicate data such as test results to a user interface **122**. The user interface **122** may provide a data display to an operator and allow for operator input. In various embodiments, the tool control application **110** may pause the device testing program **108** until the operator provides an input, generally via the user interface **122**. In another embodiment, the tool control application **110** may control various peripherals, such as handler **104**, for handling the DUT **106** and other handler operations. The tool control application **110** may control the handler **104** to place a DUT **106** into a testing position within the test cell **100**, clean a probe, position a probe at a DUT, and adjust a pressure of the probe at the DUT **106**, for example. The tool control application **110** may further assemble data files and transmit the data files over an interface to a storage location **130** or user interface **122**. In various embodiments, the tool control application **110** may control the selection of DUTs **106** for testing or for retesting. Based on obtained measurement data, the tool control application **110** may select a DUT **106** for further testing, data collection, characterization tests, etc. The tool control application **110** may further select a specific program for running at the device test program **108**.

In various embodiments, control of a behavior of the test cell **100** is enabled by communication between data sniffer **114**, adaptive-test rule engine **118** and tool control application **110**. Exemplary data sniffer **114** intercepts or extracts test data that is generated by the device test program **108**. In various embodiments, the data sniffer **114** may extract the test data as soon as it is generated, i.e., in real time. The test data may be sent from the data sniffer **114** to the adaptive-test rule engine **118** for analysis. The adaptive-test rule engine **118** analyzes the received test data and determines one or more adaptation commands that may be implemented. The adaptive-test rule engine **118** may evaluate the test data with respect to various rules, algorithms and configuration data supplied to the adaptive-test rule engine **118**. The adaptation commands may also be referred to as requests or directives. The adaptation commands may be related to the running of the device test program **108**. Alternately, the adaptation commands may be related to a behavior of the test cell **100**. The adaptation commands are sent from the adaptive-test rule engine **118** to the tool control application **110**. When the adaptation command is related to the device test program **108**, the tool control application **110** may send the adaptation command to the device test program **108** to be implemented therein. Otherwise, the tool control application **110** may implement the adaptation command itself so as to affect the tool cell behavior.

Exemplary adaptation commands for affecting the behavior are discussed below. When devices are being retested based on results observed in a prior test, an adaptation command may be applied to stop the retesting of certain DUTs **106** when it is determined that the test is not recovering any previously-failed devices. The adaptation command may cause tests in which the DUTs **106** pass with a certain regularity to be disabled, discontinued, or applied only on a subset of the DUTs **106**. The adaptation command may also dynamically adjust applied condition settings or test limit values with a test program. The adaptation command may cause additional tests to be applied to a DUT **106** when an abnormal condition or test result is detected. An adaptation command may direct the tool control application **110** to wait for operator instruction based on analysis of data not available to the tool control application **110**. Another adaptation command may direct the tool control application **110** to modify a strategy for characterizing a sample of DUTs **106**. Another adaptation command may direct the tool control application **110** to control the handler **104** to perform various functions, such as cleaning of wafer probes or adjusting a probe pressure with respect to the DUT **106**, for example. Another exemplary adaptation command may direct the tool control application **110** to alter a method of stepping through a test sample of DUTs **106**. The step plan may be based on test results and/or analysis of test results on nearest neighbor DUTs or DUTs within a selected proximity to the DUT. Adaptation commands may be based on various parameters, such as sort counts, statistical analysis of parametric values, pass/fail counts, correlations among parametric test values, for example. The adaptation command is generally determined using rules, algorithms and configuration data related to the product type, a selected test pass, a manufacturing or engineering session or other parameter.

In one embodiment, the adaptive-test rule engine **118** makes the tool control application **110** aware of active adaptive testing. Separation of the adaptive-test rule engine **118** from the tool control application **110** allows flexibility in the supervision of the device test program **108** and operation of the test cell **100**. For example, since the tool control application is an independent program from the adaptive-test rule engine **118**, the tool control application **110** may reinstate a test which has been disabled by an adaptation command provided by the adaptive-test rule engine **118**. This flexibility enables the device test program **108** to test and characterize DUTs **106** in a time-saving manner.

The adaptive-test rule engine may also take advantage of various functions performed by the tool control application **110**. For example, the tool control application **110** manages and transmits data files as well as inserting new data records into the data files. The adaptive-test rule engine **118** may therefore use the tool control application **110** to inject into the data records various setup information and the adaptation commands that are implemented during testing. The history of the adaptive testing may therefore become an integral part of the test data associated with a DUT **106**, thereby allowing for a greater interpretation of the test data. In another function, the tool control application **110** may send events to an external dashboard application, which in turn may generate notifications in various forms for subscribing users. The adaptive-test rule engine **118** may therefore use the tool control application **110** to inform operators or manufacturing personal about significant situations such as setup errors, alarms, etc.

FIG. **2** shows an exemplary schematic drawing of an alternate embodiment of the test cell **200**. The test cell **200** includes the tool control application **202**, the device test program **204** and the adaptive-test rule engine **206**. The tool control application **202** may include a main program **212** for performing functions of the tool control application **202** and an adaptive interface **214**. The device test program **204** includes at least a device-specific test program **220** and a data sniffer **210**. The device-specific test program **220** includes an adaptive API **218**. The adaptive interface **214** provides a first interface to the adaptive API **218** of the device test program **204** that provides a direct communication link between the tool control application **202** and the device testing program **204**. Adaptation commands are sent from the tool control application to the device testing program **204** over the first interface. The tool control application **202** includes a second interface with the adaptive-test rule engine **206** for data communication. In one embodiment, the tool control application receives adaptation commands and/or directives from the adaptive-test rule engine **206** through this second interface. The tool control application may further include a third interface for sending data for to a storage location **230**.

The adaptive-test rule engine **206** is shown coupled to various rules databases **208**, configuration files **209** and algorithms database **210**. Entries in the rules database **208** are generally device-specific and may be supplied to the adaptive-test rule engine **206** when the specific device is under test. The configuration database **209** customizes the adaptive-test engine to run on a particular tester and communicate with the tool control application **202** and data sniffer **210** components on that tester. The algorithms database **210** supplies implementations of generic adaptive-test strategies or techniques; information from the product-specific rules database entry **208** selects which algorithms to apply and customizes their behavior for a particular product. Thus, in various embodiments, the adaptive-test rule engine **206** is an open system and the rules, configurations and algorithms may be dynamically loaded into the adaptive-test rule engine **206**. New algorithms and rules may be implemented and installed into the system without having to make changes to the underlying adaptive-test rule engine **206**. Thus, rules development, etc., may be kept separate from maintenance of the adaptive-test rule engine **206**. Keeping product-specific settings separate from the rules and algorithms, etc., increases test cell flexibility and promotes development of reusable techniques which may more easily be extended to multiple products. The adaptive-test rule engine **206** may use network transactions to access long-term data storage either directly or via the tool control application **202**.

The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the disclosure. As used herein, the singular forms "a", "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms "comprises" and/or "comprising," when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one more other features, integers, steps, operations, element components, and/or groups thereof.

The corresponding structures, materials, acts, and equivalents of all means or step plus function elements in the claims below are intended to include any structure, material, or act for performing the function in combination with other claimed elements as specifically claimed. The description of the present disclosure has been presented for purposes of illustration and description, but is not intended to be exhaustive or limited to the disclosure in the form disclosed. Many modifications and variations will be apparent to those of ordinary skill in the art without departing from the scope and spirit of the disclosure. The embodiment was chosen and described in order to best explain the principles of the disclosure and the practical application, and to enable others of ordinary skill in the art to understand the disclosure for various embodiments with various modifications as are suited to the particular use contemplated.

While exemplary embodiments of the disclosure have been described, it will be understood that those skilled in the art, both now and in the future, may make various improvements and enhancements which fall within the scope of the claims which follow. These claims should be construed to maintain the proper protection for the disclosure first described.

What is claimed is:

1. A system for testing a device under test (DUT), comprising:

a circuit tester;

a handler to provide a connection between the circuit tester and the DUT;

a device test program included in the circuit tester and configured to administer a plurality of tests to the DUT;

a data file for storing results of the plurality of tests administered to the DUT;

a tool control application included in the circuit tester and configured to provide a user interface and to coordinate an operation of the handler and the device test program;

a real-time rule engine configured to send an adaptation command to the tool control application, wherein the tool control application implements the adaptation command and separately supervises the operation of the circuit tester; and

a data sniffer coupled to the data file and the real-time rule engine to intercept test results data as they are generated by the device test program and forward the test results to the real-time rule engine.

2. The system of claim **1**, wherein the tool control application is further configured to control operation of the device test program to test the DUT.

3. The system of claim **2**, wherein the tool control application is configured to send the adaptation command to the device test program and the device test program is configured to use the adaptation command to perform at least one of: initiating a test; discontinuing a test; pausing a test; and restarting a test.

4. The system of claim **1**, wherein the tool control application is further configured to use the adaptation command to alter a parameter related to a behavior of the circuit tester.

5. The system of claim **4**, wherein the tool control application is further configured to use the adaptation command to perform at least one of: selecting the DUT; coupling a probe to the DUT; cleaning a probe; compiling data; storing data; communicating data to the user interface; and obtaining instructions from a user at the user interface.

6. The system of claim **1**, wherein the rule-time rule engine is further configured to connect to a DUT-specific database of one or more rules and dynamically load the one or more rules into the real-time rule engine when a corresponding device is selected for testing.

7. The system of claim **1**, wherein the DUT further comprises a wafer selected from a plurality of wafers, and the tool control application is further configured to determine a testing order of the plurality of wafers.

8. The system of claim **1**, wherein the tool control application is further configured to store the adaptation command with test data obtained using the adaptation command.

9. The system of claim **1**, wherein the tool control application further comprises:

a first interface configured to provide a signal that controls an operation of the system; and

a second interface configured to receive the adaptation command from the real-time rule engine based on an evaluation of data obtained by the device test program, wherein the tool control application is configured to control the operation of the system using the received adaptation command.

10. The system of claim **9**, wherein the adaptation command is directed to control an operation of the device test program and the tool control application is further configured to send the adaptation command to the device test program.

11. The system of claim **9**, wherein the adaptation command is related to a behavior of the circuit tester that includes the device test program and the tool control application is further configured to use the adaptation command to control the behavior.

12. The system of claim **9**, wherein the first interface is configured to receive the adaptation command from the real-time rule engine.

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